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Whiteman, Jr. et al.

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(54) **ELECTRICAL CONNECTOR**

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(51) **Int. Cl.**
H01R 13/648 (2006.01)

(52) **U.S. Cl.** **439/608**

(58) **Field of Classification Search** 439/608, 439/607, 108

See application file for complete search history.

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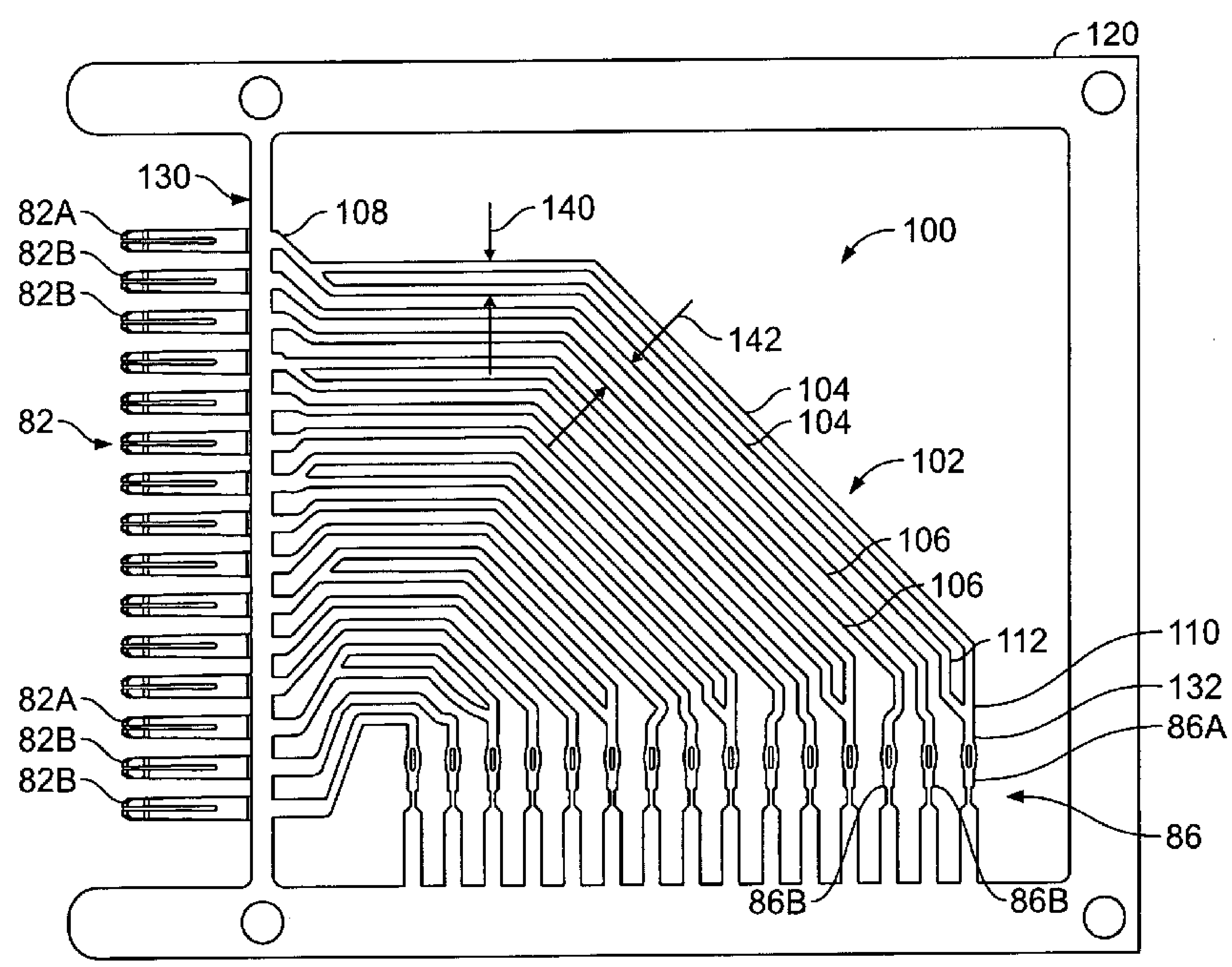
(57) **ABSTRACT**

An electrical connector includes a housing and a plurality of contact modules in the housing. Each contact module includes a mating edge and a mounting edge. Each mating and mounting edge has a row of contacts including signal and ground contacts arranged in one of a first and second pattern. Adjacent contact modules in the housing have a different one of the first and second patterns. The first and second patterns each include pairs of signal contacts and individual ground contacts arranged in an alternating sequence. Each mating edge contact is electrically connected to a corresponding mounting edge contact by signal conductors and ground conductors extending along a predetermined path within the contact module. Each ground conductor has a width transverse to the predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent contact module. The ground conductor shields the pair of signal conductors in the adjacent contact module.

17 Claims, 10 Drawing Sheets



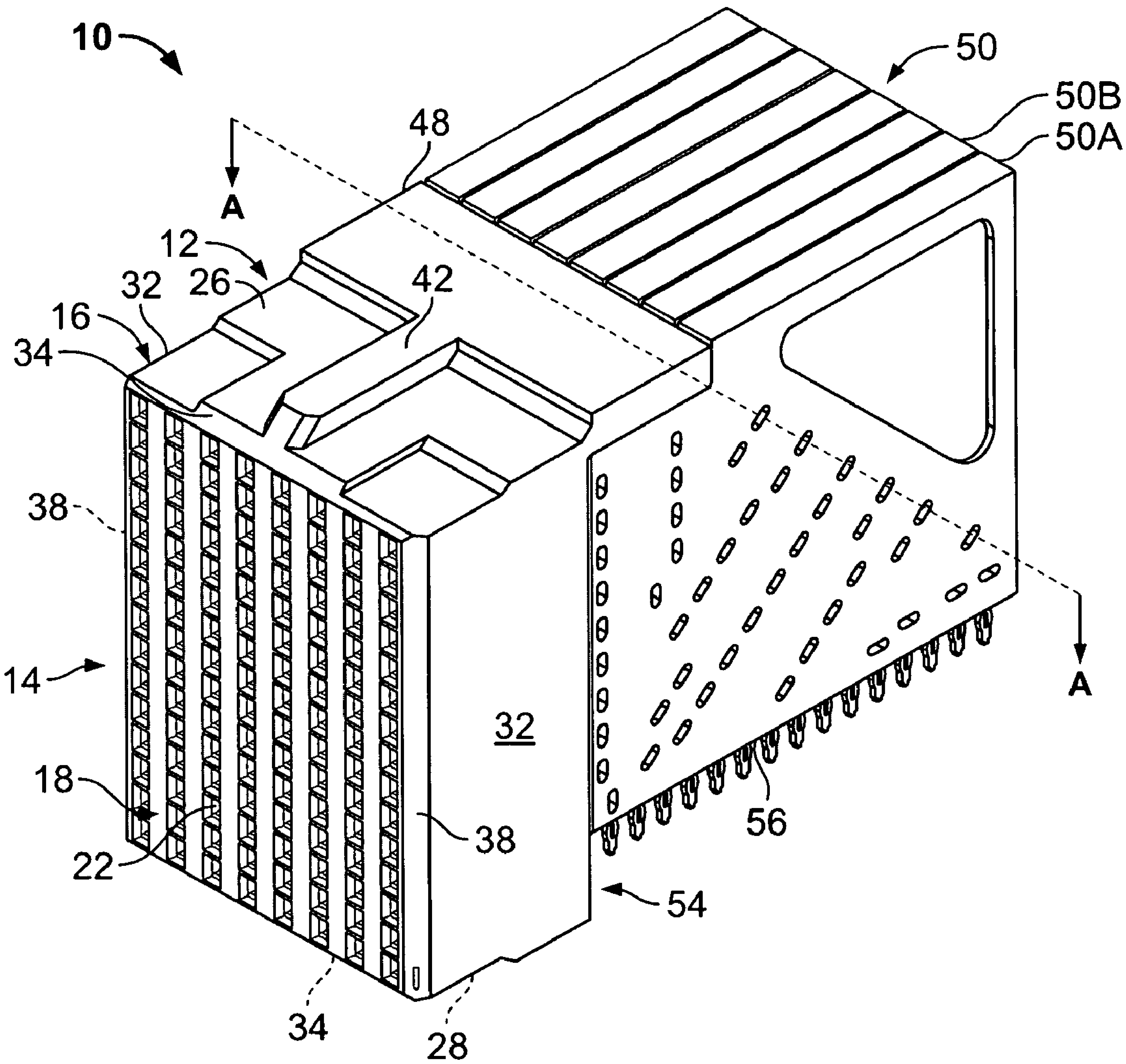


FIG. 1

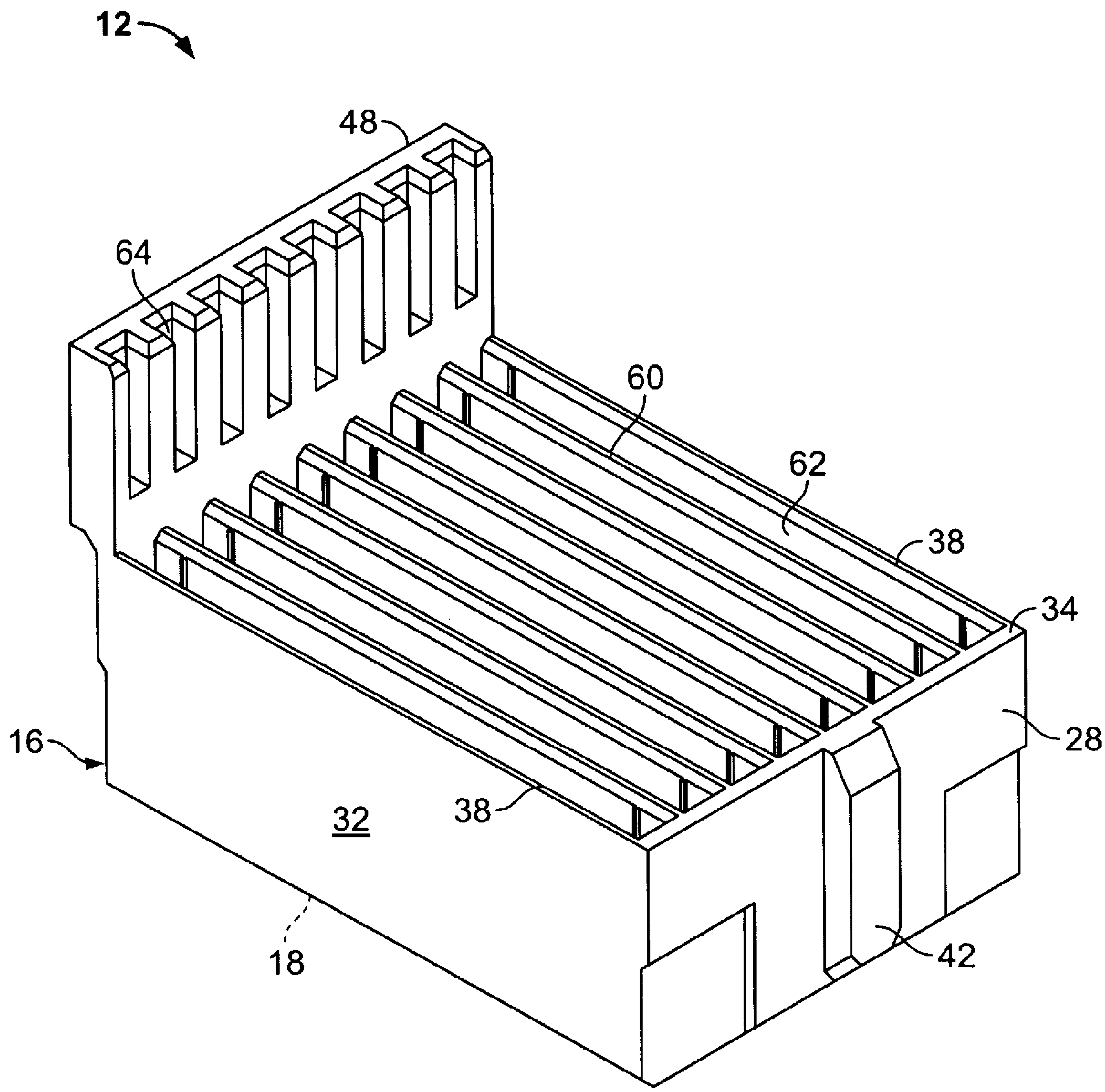
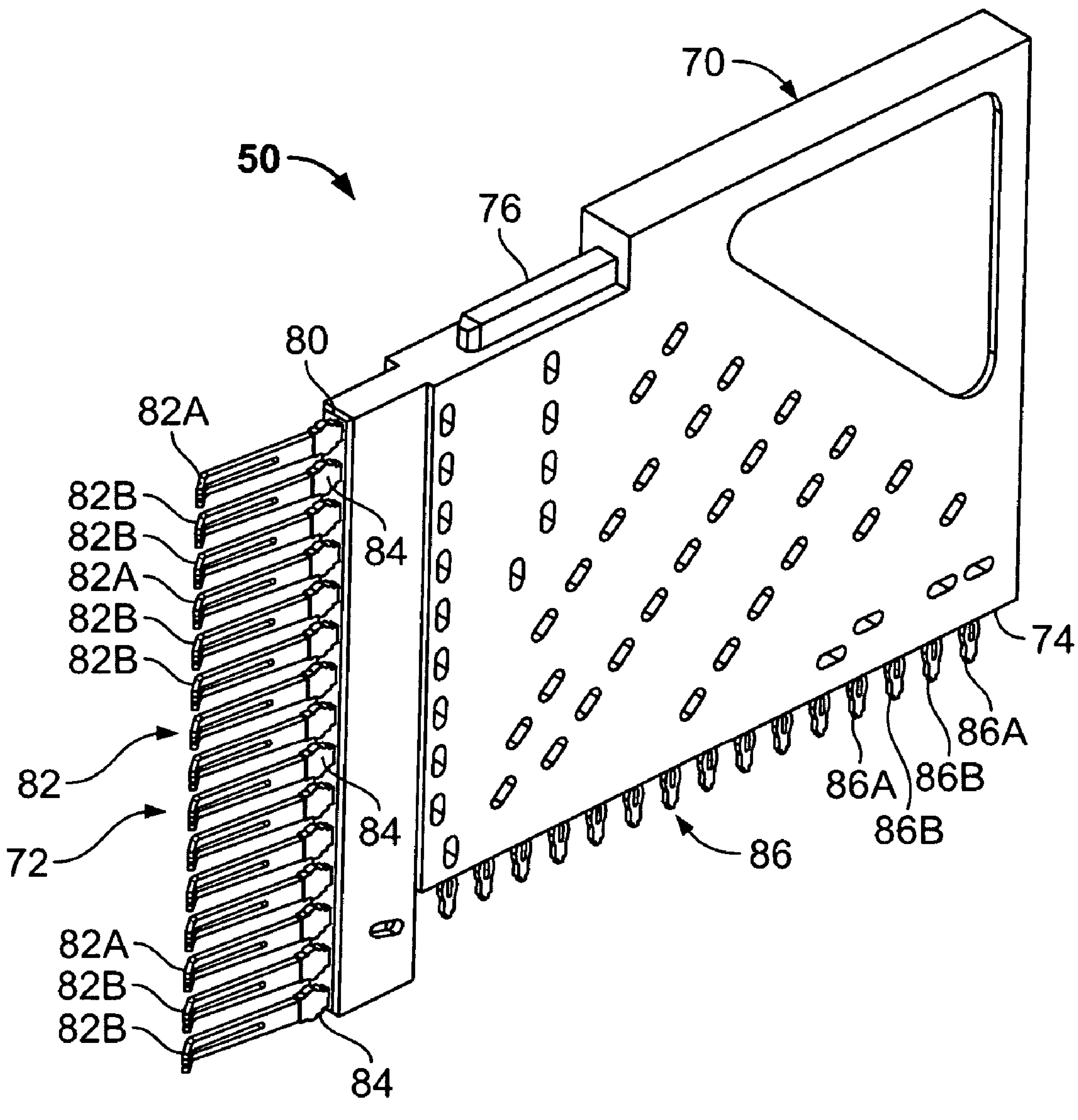


FIG. 2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50
76
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82B
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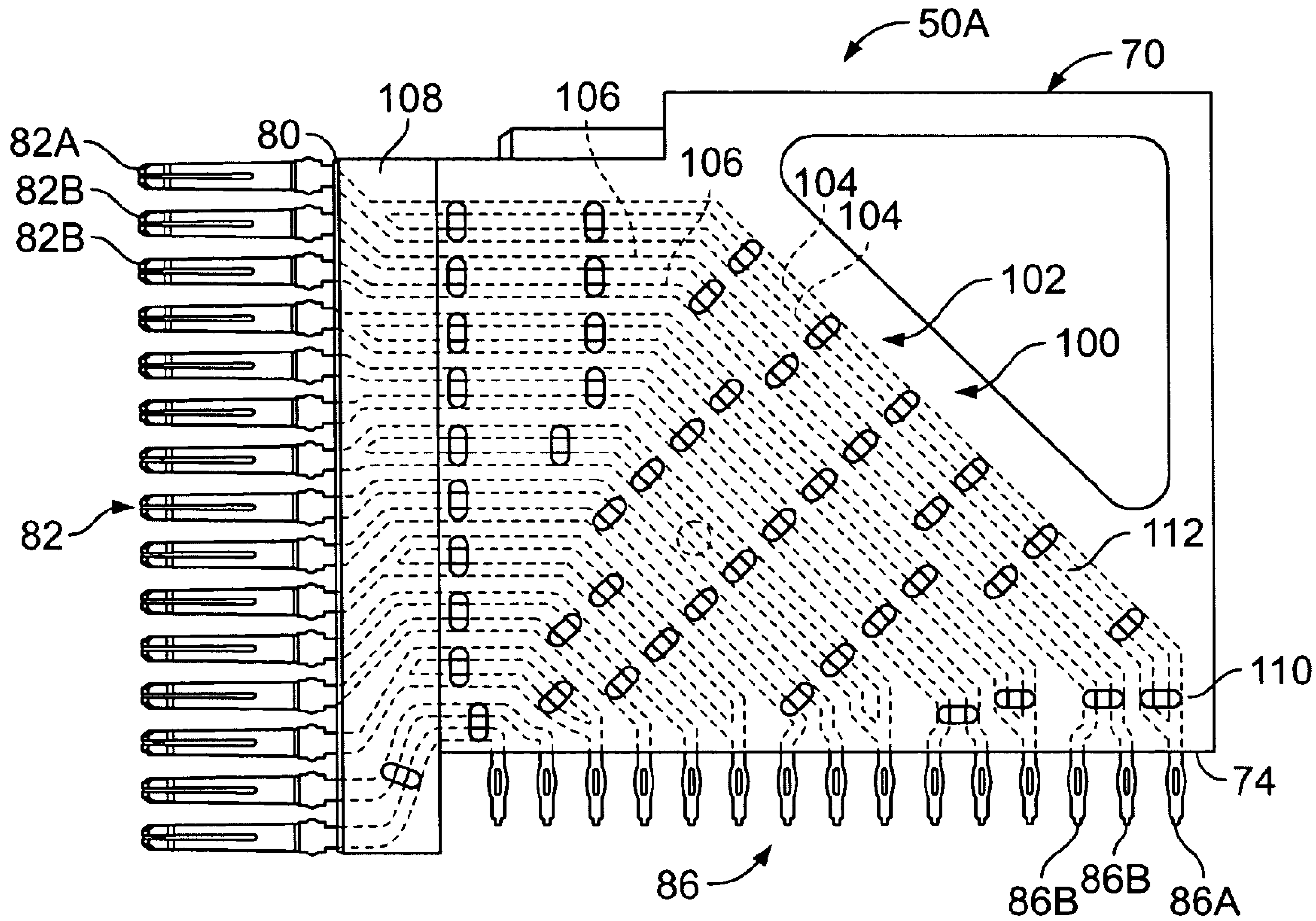
74
86A
86A
86B
86B
86

FIG. 3


50A
70
108
106
80
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104
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82
112
110
74
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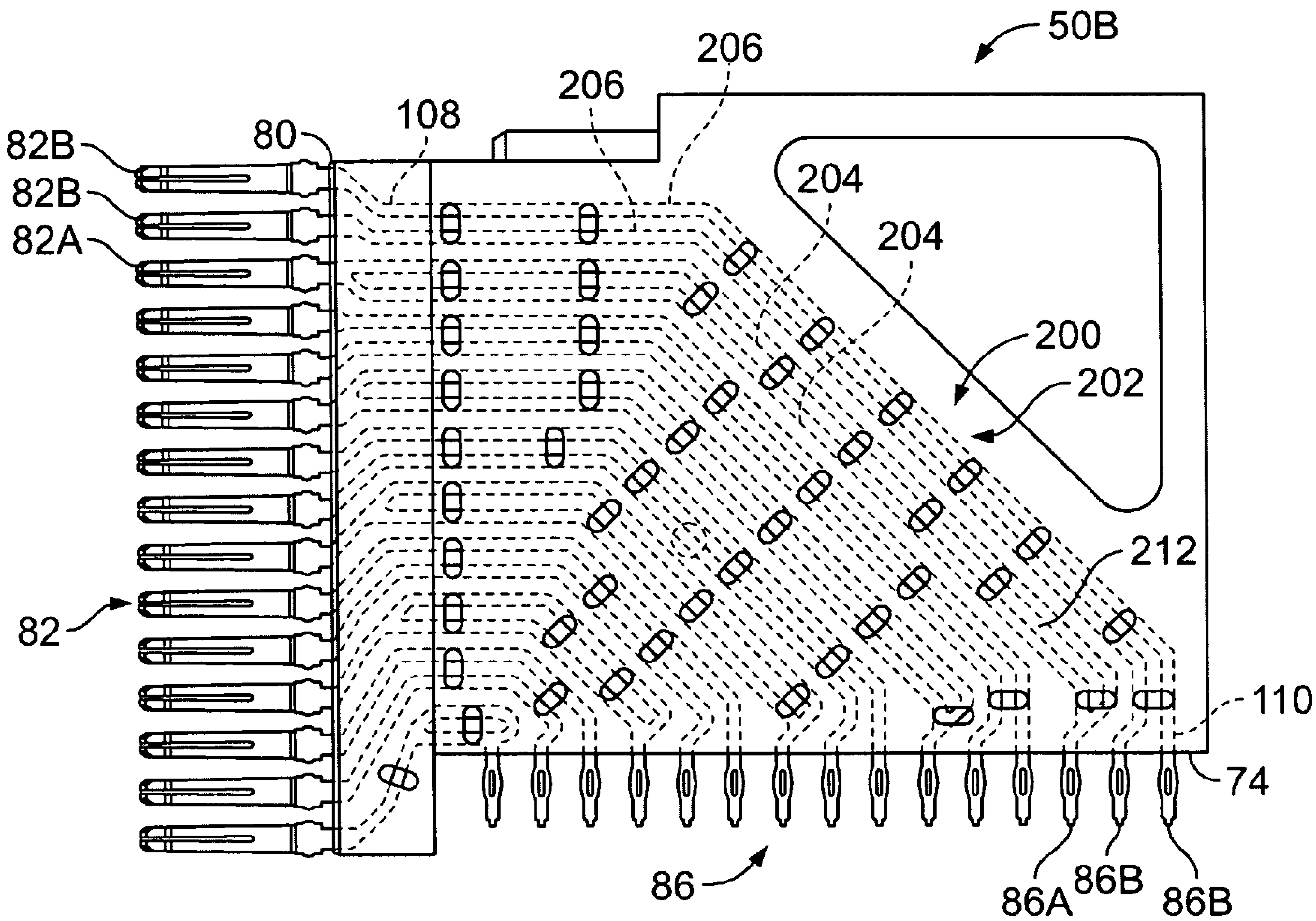
86B
86A

FIG. 4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206
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108
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82A
204
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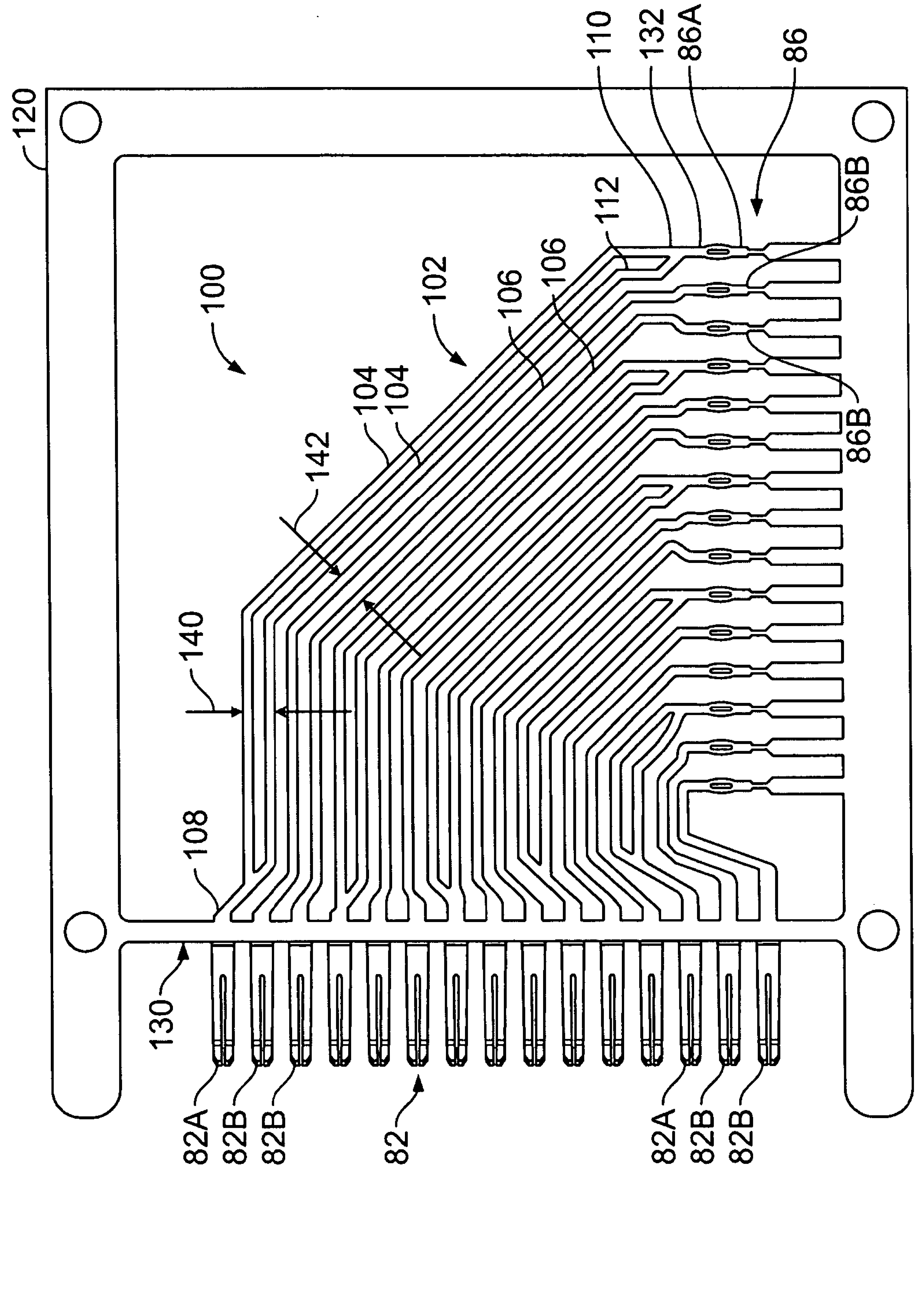
200
202
212
82
110
74
86
86A
86B
86B

FIG. 5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110
132
86A
86
86B
112
100
102
106
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86B
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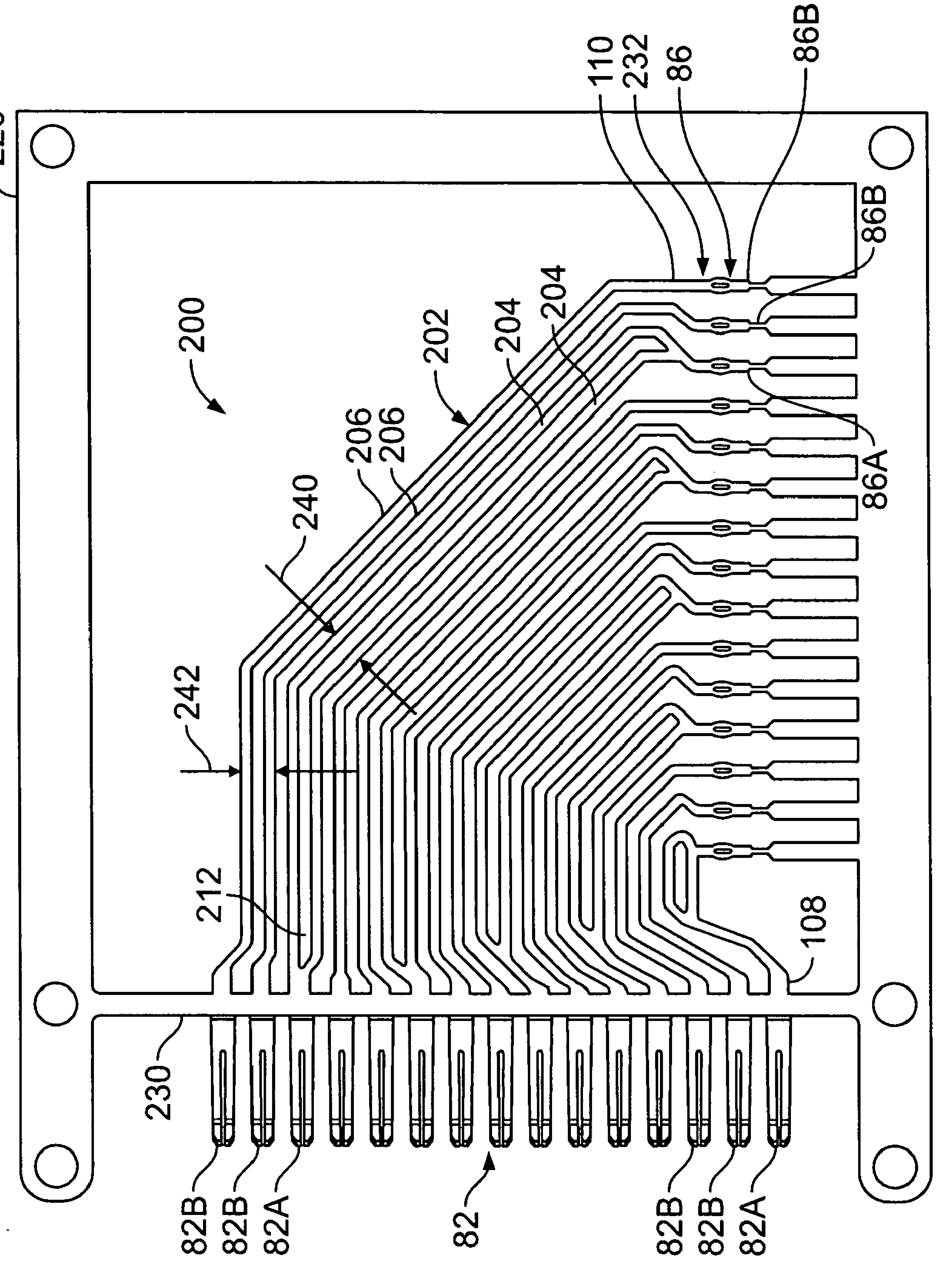
82A
82B
82B

FIG. 6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240
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230
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232
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108
82
82B
82B
82A
82B
82B
82A

FIG. 7

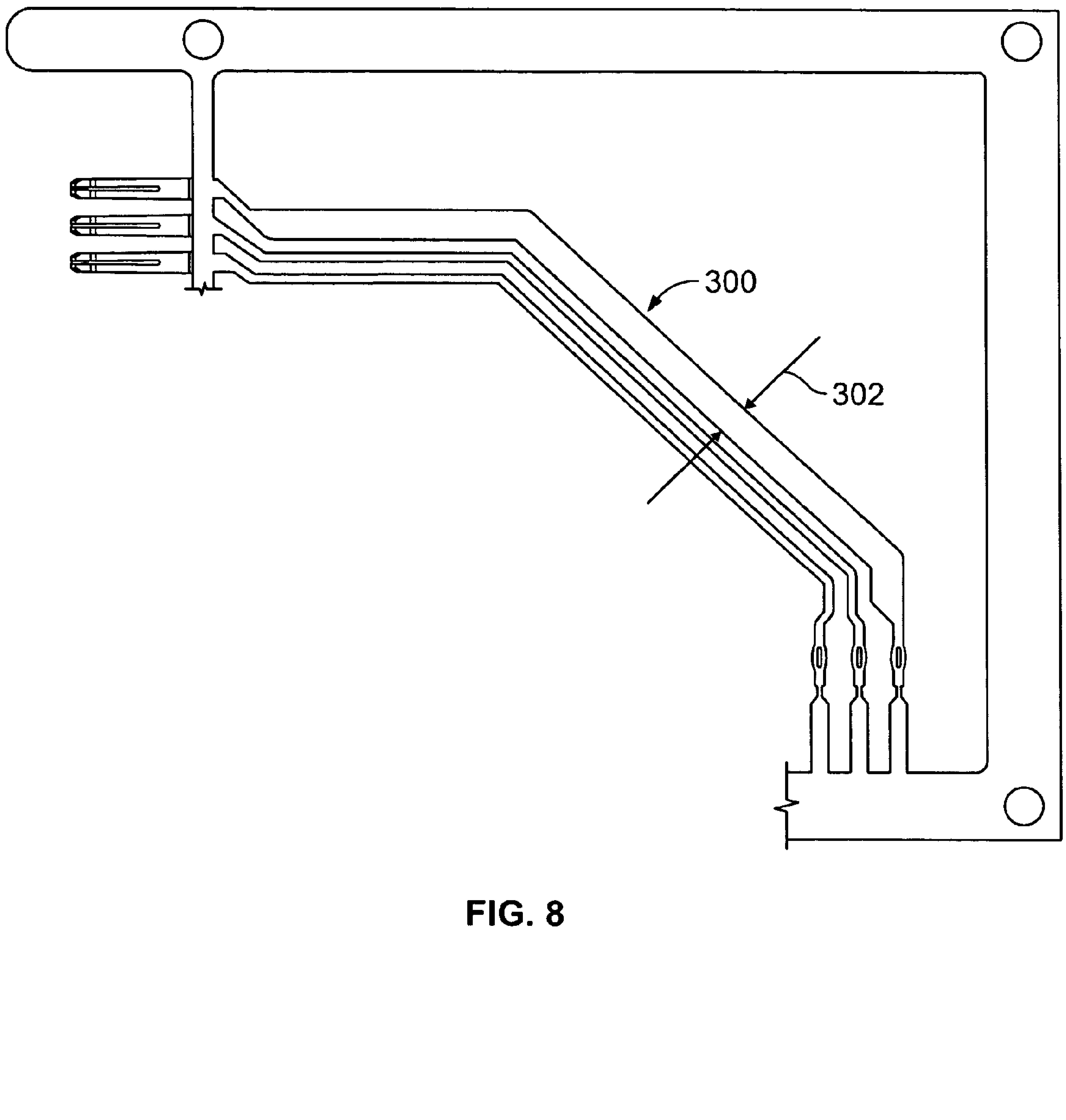


FIG. 8

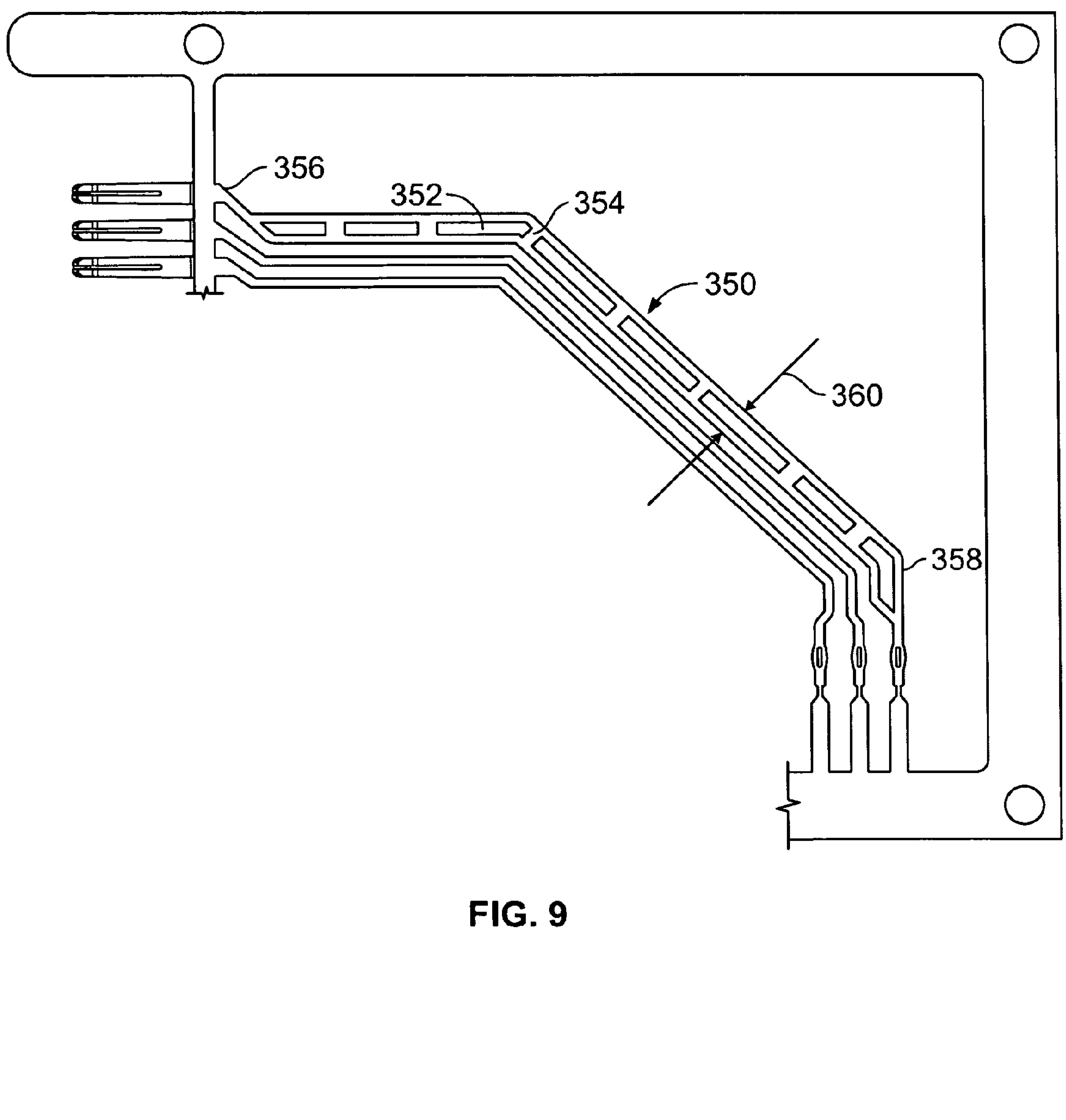
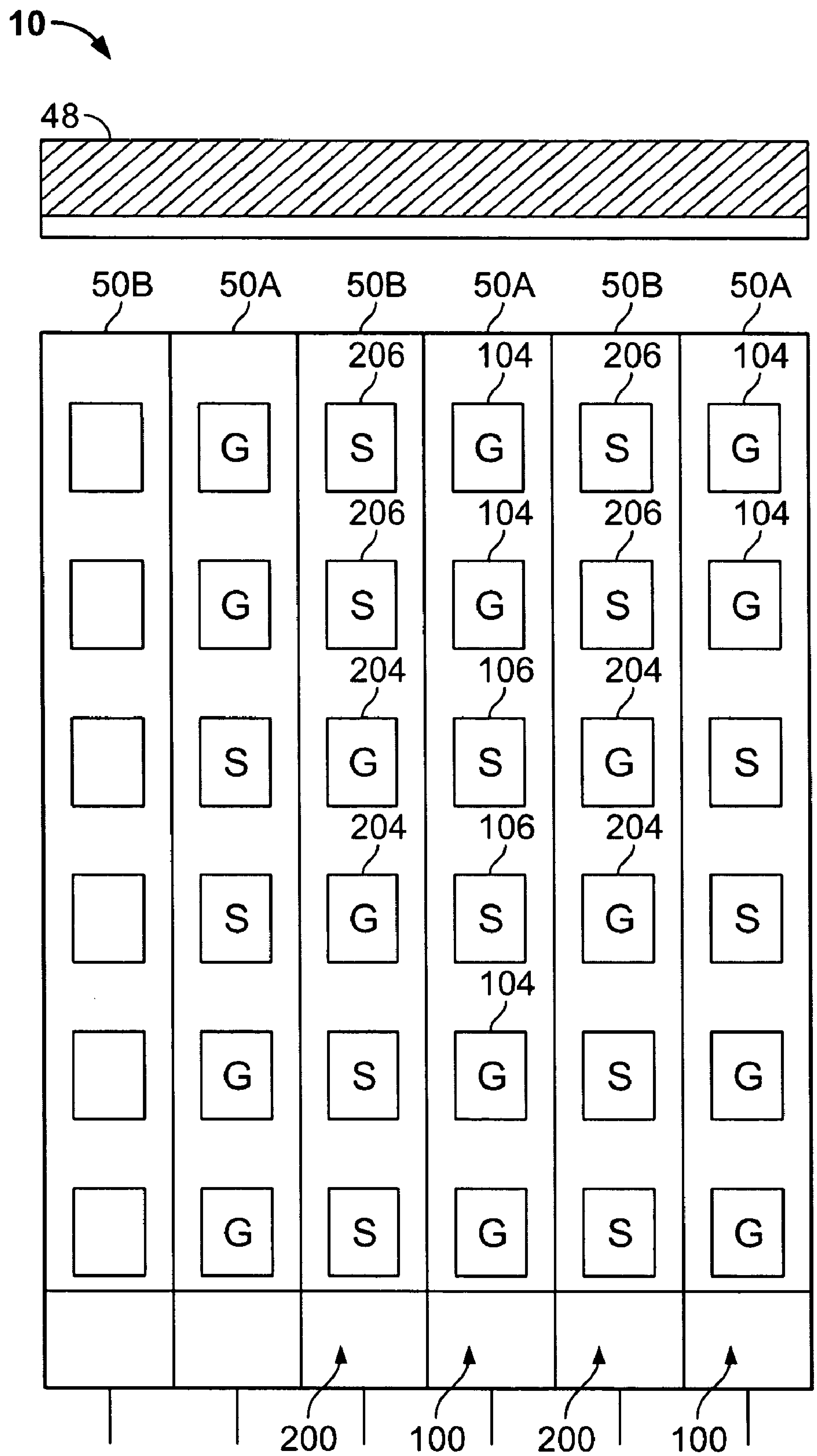


FIG. 9


10
48
50B
50A
50B
50A
50B
50A
206
104
206
104
G
S
G
S
G
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104
206
104
G
S
G
S
G
204
106
204
S
G
S
G
S
204
106
204
S
G
S
G
S
104
G
S
G
S
G
G
S
G
S
G
200
100
200
100

FIG. 10

ELECTRICAL CONNECTOR

BACKGROUND OF THE INVENTION

The invention relates generally to electrical connectors and, more particularly, to an electrical connector for transmitting signals in differential pairs.

With the ongoing trend toward smaller, faster, and higher performance electrical components such as processors used in computers, routers, switches, etc., it has become increasingly important for the electrical interfaces along the electrical paths to also operate at higher frequencies and at higher densities with increased throughput.

In a traditional approach for interconnecting circuit boards, one circuit board serves as a back plane and the other as a daughter board. The back plane typically has a connector, commonly referred to as a header, that includes a plurality of signal pins or contacts which connect to conductive traces on the back plane. The daughter board connector, commonly referred to as a receptacle, also includes a plurality of contacts or pins. Typically, the receptacle is a right angle connector that interconnects the back plane with the daughter board so that signals can be routed between the two. The right angle connector typically includes a mating face that receives the plurality of signal pins from the header on the back plane, and contacts that connect to the daughter board.

At least some board-to-board connectors are differential connectors wherein each signal requires two lines that are referred to as a differential pair. For better performance, a ground contact is associated with each differential pair. The receptacle connector typically includes a number of modules having contact edges that are at right angles to each other. The modules may or may not include a ground shield. As the transmission frequencies of signals through these connectors increase, it becomes more desirable to maintain a desired impedance through the connector to minimize signal degradation. A ground shield is sometimes provided on the module to reduce interference or crosstalk. In addition, a ground shield may be added to the ground contacts on the header connector. Improving connector performance and increasing contact density to increase signal carrying capacity without increasing the size of the connectors is challenging.

Some older connectors, which are still in use today, operate at speeds of one gigabit per second or less. By contrast, many of today's high performance connectors are capable of operating at speeds of up to ten gigabits or more per second. As would be expected, the higher performance connector also comes with a higher cost.

A need remains for a low cost differential connector with improved electrical characteristics such as reduced crosstalk and increased throughput.

BRIEF DESCRIPTION OF THE INVENTION

In one aspect, an electrical connector is provided that includes a housing and a plurality of contact modules in the housing. Each contact module includes a mating edge and a mounting edge. Each mating and mounting edge has a row of contacts including signal contacts and ground contacts arranged in one of a first and second pattern. Adjacent contact modules in the housing have a different one of the first and second patterns. The first and second patterns each include pairs of signal contacts and individual ground contacts arranged in an alternating sequence. Each mating edge contact is electrically connected to a corresponding mounting edge contact by signal conductors and ground conductors extending along a predetermined path within the contact module. Each ground conductor has a width transverse to the predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent contact module. The ground conductor thereby shields the pair of signal conductors in the adjacent contact module when the contact modules are arranged in the housing.

Optionally, each contact module further includes transition regions that join each signal and ground contact to one of the conductors. The ground conductors may include a slot extending longitudinally between the transition regions. Alternatively, the ground conductors may include a plurality of slots extending longitudinally between the transition regions, wherein the plurality of slots define a plurality of reinforcing bars therebetween.

In another aspect, an electrical connector is provided that includes a housing and a plurality of contact modules in the housing. The contact modules carry differential signals. Each contact module includes a mating edge and a mounting edge. Each mating and mounting edge has a row of contacts including signal contacts arranged in differential pairs and individual ground contacts. The signal and ground contacts are arranged in one of a first and second pattern, and adjacent contact modules in the housing have a different one of the first and second patterns. The first and second patterns each include pairs of differential signal contacts and individual ground contacts arranged in an alternating sequence. Each mating edge contact is electrically connected to a corresponding mounting edge contact by signal conductors and ground conductors extending along a predetermined path within the contact module. The ground conductors in each contact module cooperate with ground conductors in adjacent contact modules to substantially isolate each differential signal conductor pair from other signal conductors to reduce crosstalk in the connector when the contact modules are arranged in the housing.

In yet another aspect, a lead frame for an electrical contact module is provided. The lead frame includes a first row of mating contacts defining a forward mating edge and a second row of mounting contacts defining a mounting edge. The row of mating contacts and mounting contacts each include signal contacts and ground contacts arranged in one of a first and second pattern. The first and second patterns each include pairs of signal contacts and individual ground contacts arranged in an alternating sequence. Each mating edge signal and ground contact is electrically connected to a corresponding mounting edge signal and ground contact by signal conductors and ground conductors extending along a predetermined path within the lead frame. Each ground conductor has a width transverse to the predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent lead frame having contacts arranged in the other of the patterns. The ground conductor thereby shields the pair of signal conductors in the adjacent lead frame.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an electrical connector formed in accordance with an exemplary embodiment of the present invention.

FIG. **2** is a rear perspective view of the housing of the connector shown in FIG. **1**.

FIG. **3** is a perspective view of a contact module formed in accordance with an exemplary embodiment of the present invention.

FIGS. **4** and **5** are side views of a contact module showing internal lead paths, in phantom outline, according to one embodiment of the present invention.

FIG. **6** is a side view of the lead frame in the contact module shown in FIG. **4**.

FIG. **7** is a side view of the lead frame in the contact module shown in FIG. **5**.

FIG. **8** is a side view of a partial lead frame illustrating a ground conductor formed in accordance with an alternative embodiment of the present invention.

FIG. **9** is a side view of a partial lead frame illustrating a ground conductor formed in accordance with another alternative embodiment of the present invention.

FIG. **10** is a partial cross sectional view of the connector shown in FIG. **1** taken along the line A—A.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** illustrates an electrical connector **10** formed in accordance with an exemplary embodiment of the present invention. While the connector **10** will be described with particular reference to a receptacle connector, it is to be understood that the benefits herein described are also applicable to other connectors in alternative embodiments. The following description is therefore provided for purposes of illustration, rather than limitation, and is but one potential application of the inventive concepts herein.

The connector **10** includes a dielectric housing **12** having a forward mating end **14** that includes a shroud **16** and a mating face **18**. The mating face **18** includes a plurality of contact cavities **22** that are configured to receive mating contacts (not shown) from a mating connector (not shown). The shroud **16** includes an upper surface **26** and a lower surface **28** between opposed sides **32**. The upper and lower surfaces **26** and **28**, respectively, each includes a chamfered forward edge **34**. The sides **32** each includes chamfered side edges **38**. An alignment rib **42** is formed on the upper shroud surface **26** and lower shroud surface **28**. The chamfered edges **34** and **38** and the alignment ribs **42** cooperate to bring the connector **10** into alignment with the mating connector during the mating process so that the contacts in the mating connector are received in the contact cavities **22** without damage.

The housing **12** also includes a rearwardly extending hood **48**. A plurality of contact modules **50** are received in the housing **12** from a rearward end **54**. The contact modules **50** define a connector mounting face **56**. In an exemplary embodiment, the mounting face **56** is substantially perpendicular to the mating face **18** such that the connector **10** interconnects electrical components that are substantially at a right angle to one another. The contact modules **50** include two module types, **50**A and **50**B as will be described.

FIG. **2** illustrates a rear perspective view of the housing **12**. The housing **12** includes a plurality of dividing walls **60** that define a plurality of chambers **62**. The chambers **62** receive a forward portion of the contact modules **50** (FIG. **1**). A plurality of slots **64** are formed in the hood **48**. The chambers **62** and slots **64** cooperate to stabilize the contact modules **50** when the contact modules **50** are loaded into the housing **12**.

FIG. **3** illustrates a perspective view of a contact module **50** formed in accordance with an exemplary embodiment of the present invention. The contact module **50** includes a lead frame (not shown in FIG. **3**) that is over-molded in a dielectric housing **70**. The contact module **50** has a forward mating end **72** and a mounting edge **74**. The housing **70** includes an alignment rib **76** formed proximate the mating end **72**. The mating end **72** is received in one of the chambers **62** in the housing **12** (FIG. **2**). The alignment rib **76** is sized to be received in one of the slots **64** in the housing **12**. The mating end **72** of the contact module **50** includes a mating edge **80** that holds a linear row of mating contacts **82**. Each of the mating contacts **82** extends from a retaining bump **84** proximate the mating edge **80**. The retaining bumps **84** engage interior webs (not shown) in the housing **12** proximate the mating end **14** to retain the contact module **50** in the housing **12**. In one embodiment, the mating contacts **82** are spring contacts. However, other contact configurations may be used in other embodiments.

A row of mounting contacts **86** extend along the contact module mounting edge **74**. In an exemplary embodiment, the mounting contacts **86** are eye-of-the-needle contacts and are configured to be mounted to a circuit board (not shown). In other embodiments, the mounting edge **74** may be joined to an electrical component using other known contact types. Electrical paths within the contact module **50** interconnect the mating and mounting contacts **82** and **86** respectively. In an exemplary embodiment, the mating edge **80** and the mounting edge **74** are substantially perpendicular to one another.

The mating contacts **82** and mounting contacts **86** include both signal and ground contacts arranged in one of a first and second pattern that each includes pairs of signal contacts and individual ground contacts arranged in an alternating sequence. For example, in the first pattern, mating contacts **82**A are ground contacts and contacts **82**B are signal contacts. Similarly, along the mounting edge **74**, mounting contacts **86**A are ground contacts and mounting contacts **86**B are signal contacts. Conductors within the contact module **50** interconnect mating ground and signal contacts **82**A and **82**B, respectively, with corresponding ground and signal mounting contacts **86**A and **86**B, respectively. The pairs of adjacent signal contacts **82**B and **86**B, at the mating edge **80** and the mounting edge **74**, respectively, form a differential signal pair carrying differential signals. In the second contact pattern, the contacts **82** and **86** are arranged such that the two uppermost mating contacts in FIG. **3** would both be signal contacts and the third, a ground contact. Similarly, the two rightmost mounting contacts would be signal contacts, and the third, a ground contact. From its outward appearance, the particular contact pattern in the contact module **50** cannot be discerned.

FIG. **4** is side view of a contact module **50**A that includes an internal lead frame **100** shown in phantom outline. The lead frame **100** determines the contact pattern and thus characterizes the contact module **50**A, which is in the first of the patterns described above. The lead frame **100** includes a plurality of conductors **102**, including ground conductors **104** and signal conductors **106** that extend along predetermined paths to electrically connect each mating edge contact **82** to a corresponding mounting edge contact **86**. A transition region **108** joins each mating contact **82** to one of the conductors **102** and a transition region **110** joins each mounting contact **86** to one of the conductors **102**. In an exemplary embodiment, the ground conductors **104** have a longitudinally extending slot **112** that divides the ground conductor **104** into two parts between corresponding transition regions **108** and **110**.

FIG. **5** is side view of a contact module **50**B that includes an internal lead frame **200** shown in phantom outline. The lead frame **200** determines the contact pattern and thus characterizes the contact module **50**B, which is in the second of the patterns previously described. The lead frame **200** is similar to the lead frame **100** (FIG. **4**) and includes a plurality of conductors **202**, including ground conductors **204** and signal conductors **206** that extend along predetermined paths to electrically connect each mating edge contact **82** to a corresponding mounting edge contact **86**. Transition regions **108** and **110** join each mating contact and mounting contact, respectively, to one of the conductors **202**. In an exemplary embodiment, the ground conductors **204** also have a longitudinally extending slot **212** that divides the ground conductor **204** into two parts between corresponding transition regions **108** and **110**.

FIG. **6** is a side view of the lead frame **100** that is used to form the contact module **50**A. FIG. **7** is side view of the lead frame **200** that is used to form the contact module **50**B. Each of the lead frames **100**, **200** is shown attached to carrier strips **120** and **220**, respectively, that are removed and discarded after the over-molding process that creates the contact modules **50**A and **50**B. The retaining bumps **84** (FIG. **3**) are formed when the mating contacts **82** are cut from the carrier strips **120** and **220**.

Lead frame **100** includes a first row of contacts **82** that are mating contacts and which define a forward mating edge **130** of the lead frame **100**. A second row of contacts **86** are mounting contacts and define a mounting edge **132** of the lead frame **100**. The mating contacts **82** and the mounting contacts **86** both include signal contacts **82**B, **86**B and ground contacts **82**A, **86**A arranged in a first pattern that includes pairs of signal contacts **82**B, **86**B and individual ground contacts **82**A, **86**A, arranged in an alternating sequence as previously described. The mating contacts **82** are electrically connected to corresponding mounting contacts **86** by conductors **102** that extend along predetermined paths between transition regions **108**, **110** that join the conductors **102** to the contacts **82**, **86**. The conductors **102** are arranged in the lead frame **100** in the same pattern as the contacts **82** and **86** in the lead frame **100**.

Lead frame **200** is similar to the lead frame **100** and includes a first row of contacts **82** that are mating contacts and which define a forward mating edge **230** of the lead frame **200**. A second row of contacts **86** are mounting contacts and define a mounting edge **232** of the lead frame **200**. The mating contacts **82** and the mounting contacts **86** both include signal contacts **82**B, **86**B and ground contacts **82**A, **86**A arranged in a second pattern. The pattern includes pairs of signal contacts **82**B, **86**B and individual ground contacts **82**A, **86**A, arranged in an alternating sequence as previously described. The mating contacts **82** are electrically connected to corresponding mounting contacts **86** by conductors **202** that extend along predetermined paths between transition regions **108**, **110** that join the conductors **202** to the contacts **82**, **86**. The conductors **202** are arranged in the lead frame **200** in the same pattern as the contacts **82** and **86** in the lead frame **200**.

In the embodiments of FIGS. **6** and **7**, the ground conductors **104**, **204** include a longitudinally extending slot **112**, **212**, respectively, between the transition regions **108** and **110** which divides the ground conductors **104**, **204** into two parts. The ground conductors **104**, **204** have a width **140**, **240** transverse to the longitudinal path of the ground conductors **104**, **204** that is substantially equal to a combined transverse width **142**, **242** of a pair of signal conductors **106**, **206** in an adjacent lead frame **100**, **200** in an adjacent contact module **50**A, **50**B. In this manner, the ground conductors **104**, **204** shield the signal conductors **106**, **206** in the adjacent lead frame **100**, **200**. Moreover, the slots **112**, **212** are sized such that each of the divided parts of the ground conductors **104**, **204** is substantially equal in width to a width of an individual signal conductor **106**, **206**. However, in some embodiments, the size of the slots **112**, **212** may be adjusted so as to maintain a desired impedance in the signal conductors **106**, **206** in the lead frames **100**, **200**. Furthermore, in some embodiments, the widths **140**, **240** of the ground conductors **104**, **204** may vary along the length of the conductors **102**, **202** depending on the configuration of the electrical paths within the lead frames **100**, **200**. The widths **140**, **240** of the ground conductors **104**, **204** may also be varied to maintain a desired impedance in the signal conductors **106**, **206** in the lead frames **100**, **200**.

FIG. **8** illustrates an alternative embodiment of a ground conductor **300** that is a solid lead of conductive material such as copper. The solid ground conductor **300** has a width **302** transverse to the longitudinal path of the ground conductor **300** that is substantially equal to a combined transverse width of a pair of adjacent signal conductors (not shown) in an adjacent lead frame (not shown).

FIG. **9** illustrates another alternative embodiment of a ground conductor **350** that includes a plurality of slots **352** between reinforcing bars **354** along a length of the ground conductor **350** between transition regions **356** and **358**. The ground conductor **350** also has a width **360** transverse to the longitudinal path of the ground conductor **350** that is substantially equal to a combined transverse width of a pair of adjacent signal conductors (not shown) in an adjacent lead frame (not shown).

FIG. **10** illustrates a partial cross sectional view of the connector **10** taken along the line A—A in FIG. **1**. Certain of the conductors are labeled S (signal) or G (ground) to aid in identifying the conductors. The contact modules **50**A, including the lead frame **100**, and **50**B, including the lead frame **200**, are loaded into the housing **12** (FIG. **1**) in an alternating sequence when the connector **10** is assembled such that the lead frames **100**, **200** in adjacent contact modules **50**A, **50**B have different contact patterns, and more importantly different conductor patterns. Specifically, the lead frames **100** and **200** are configured such that, when the contact modules **50**A, **50**B are loaded in the housing **12**, the signal conductors **106** in each of the lead frames **100** are spacially aligned with a ground conductor **204** in an adjacent lead frame **200** of the adjacent contact module **50**B. Likewise, the signal conductors **206** in each of the lead frames **200** are spatially aligned with a ground conductor **104** in an adjacent lead frame **100** of the adjacent contact module **50**A. In this manner, the signal conductors **106**, **206**, which are arranged in differential pairs, are shielded by adjacent ground conductors **104**, **204** to reduce crosstalk in the connector **10** and facilitate increased throughput through the connector **10**. Further shielding for the signal conductors **106**, **206** is provided by ground conductors **104**, **204** above and below the signal conductors **106**, **206** in the same lead frame **100**, **200** which cooperate with the ground conductors **104**, **204** in an adjacent lead frame **100**, **200** in an adjacent contact module **50**A, SOB to substantially isolate each differential signal pair from other differential signal pairs in the connector **10**.

The embodiments herein described provide an electrical connector **10** having an improved lead frame **100**, **200** for carrying differential signals. The lead frame includes ground conductors **104**, **204** that have a transverse width that is substantially equal to a combined width of a pair of signal conductors **106**, **206** in an adjacent lead frame. The ground conductor shields the signal conductors to reduce crosstalk in the connector. The lead frame also allows the connector to operate at higher frequencies with increased throughput.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. An electrical connector comprising:

a housing; and

a plurality of contact modules in said housing;

each said contact module comprising a mating edge and a mounting edge, each said mating and mounting edges having a row of contacts including signal contacts and ground contacts arranged in one of a first and second pattern, and adjacent contact modules in said housing having a different one of said first and second patterns;

said first and second patterns each including pairs of signal contacts and individual ground contacts arranged in an alternating sequence;

each mating edge contact being electrically connected to a corresponding mounting edge contact by signal conductors and ground conductors extending along a predetermined path within said contact module;

wherein each said ground conductor has a width transverse to said predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent contact module, said ground conductor thereby shielding said pair of signal conductors in said adjacent contact module when said contact modules are arranged in said housing.

2. The connector of claim **1**, wherein each said contact module further includes transition regions that join each said signal and ground contact to one of said conductors.

3. The connector of claim **1**, wherein each said contact module further includes transition regions that join each said signal and ground contact to a respective signal conductor and ground conductor and wherein said ground conductors include a slot extending longitudinally between said transition regions.

4. The connector of claim **1**, wherein each said contact module further includes transition regions that join each said signal and ground contact to a respective signal conductor and ground conductor and wherein said ground conductors include a plurality of slots extending longitudinally between said transition regions, said plurality of slots defining a plurality of reinforcing bars therebetween.

5. The connector of claim **1**, wherein said pairs of signal contacts and signal conductors carry differential signals.

6. The connector of claim **1**, wherein each of said plurality of contact modules is received in one of a linear row of chambers in said housing.

7. The connector of claim **1**, wherein said mating edge and said mounting edge in each contact module are substantially perpendicular to each other.

8. An electrical connector comprising:

a housing; and

a plurality of contact modules in said housing, said contact modules carrying differential signals;

each said contact module comprising a mating edge and a mounting edge, each said mating and mounting edges having a row of contacts including signal contacts arranged in differential pairs and individual ground contacts, said signal and ground contacts being arranged in one of a first and second pattern, and adjacent contact modules in said housing having a different one of said first and second patterns;

said first and second patterns each including pairs of differential signal contacts and individual ground contacts arranged in an alternating sequence;

each mating edge contact being electrically connected to a corresponding mounting edge contact by signal conductors and ground conductors extending along a predetermined path within said contact module;

wherein said ground conductors in each said contact module cooperate with ground conductors in adjacent contact modules to substantially isolate each differential signal conductor pair from other signal conductors to reduce crosstalk in the connector when said contact modules are arranged in said housing; and

wherein said signal and ground contacts and said signal and ground conductors in each said contact module comprise a lead frame, said lead frame including a plurality of retaining bumps that engage said housing to retain said contact module in said housing.

9. The connector of claim **8**, wherein each said mating edge contact in said contact module extends from one of said retaining bumps.

10. The connector of claim **8**, wherein each said ground conductor has a width transverse to said predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent contact module, such that said ground conductor shields said pair of signal conductors in said adjacent contact module.

11. A lead frame for an electrical contact module, said lead frame comprising:

a first row of contacts comprising mating contacts and defining a forward mating edge; and

a second row of contacts comprising mounting contacts and defining a mounting edge;

said row of mating contacts and mounting contacts each including signal contacts and ground contacts arranged in one of a first and second pattern;

said first and second patterns each including pairs of signal contacts and individual ground contacts arranged in an alternating sequence;

each mating edge signal and ground contact being electrically connected to a corresponding mounting edge signal and ground contact by signal conductors and ground conductors extending along a predetermined path within the lead frame;

wherein each said ground conductor has a width transverse to said predetermined path that is substantially equal to a combined transverse width across a pair of signal conductors in an adjacent lead frame having contacts arranged in the other of said patterns, said ground conductor thereby shielding said pair of signal conductors in said adjacent lead frame.

12. The lead frame of claim **11**, wherein each said conductor includes transition regions that join said signal and ground contacts to said conductors.

13. The lead frame of claim **11**, wherein each said conductor includes transition regions that join said signal and ground contacts to said conductors and wherein said ground conductors include a slot extending longitudinally between said transition regions.

14. The lead frame of claim **11**, wherein each said conductor includes transition regions that join said signal and ground contacts to said conductors and wherein said ground conductors include a plurality of slots extending longitudinally between said transition regions, said plurality of slots defining a plurality of reinforcing bars therebetween.

15. The lead frame of claim **11**, wherein each said ground conductor comprises a solid conductive lead.

16. The lead frame of claim **11**, wherein said pairs of signal contacts and signal conductors carry differential signals.

17. The lead frame of claim **11**, wherein said mating edge and said mounting edge in each contact module are substantially perpendicular to each other.

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